



**Particle Physics Division  
Mechanical Department Engineering Note**

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Project: NOvA

Title: Stress and Deflection in FHEP Air Spring Mount

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Reviewer(s):

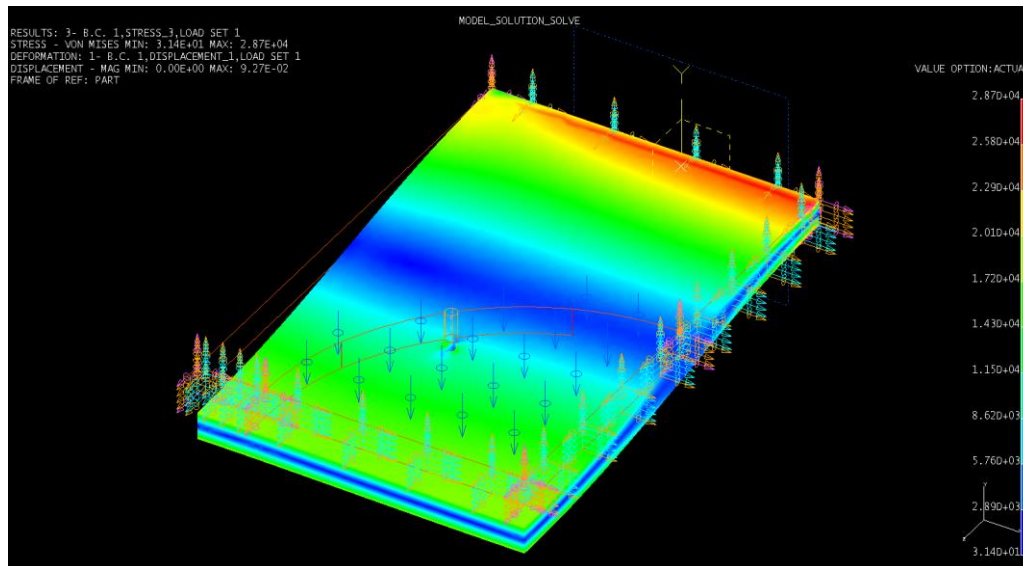
Key Words: NOvA, FHEP, Stress, Deflection

Abstract Summary: The following engineering note shows the stress and deflection in the wheel support air spring mount as part of the FHEP block pivoter. The stress and deflection are a result of the pressure exerted by the air spring.

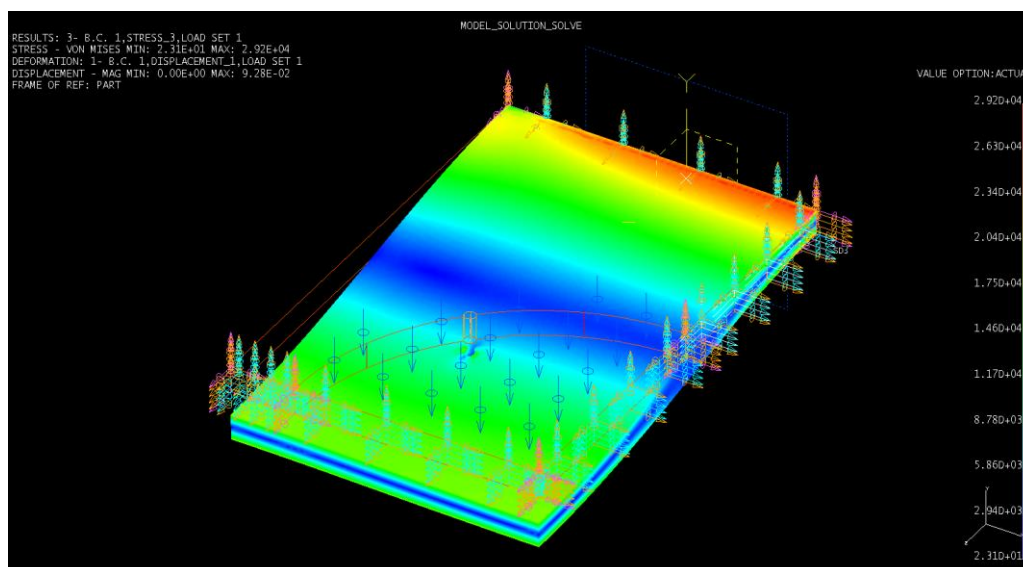
Applicable Codes:

## Initial Plate Analysis

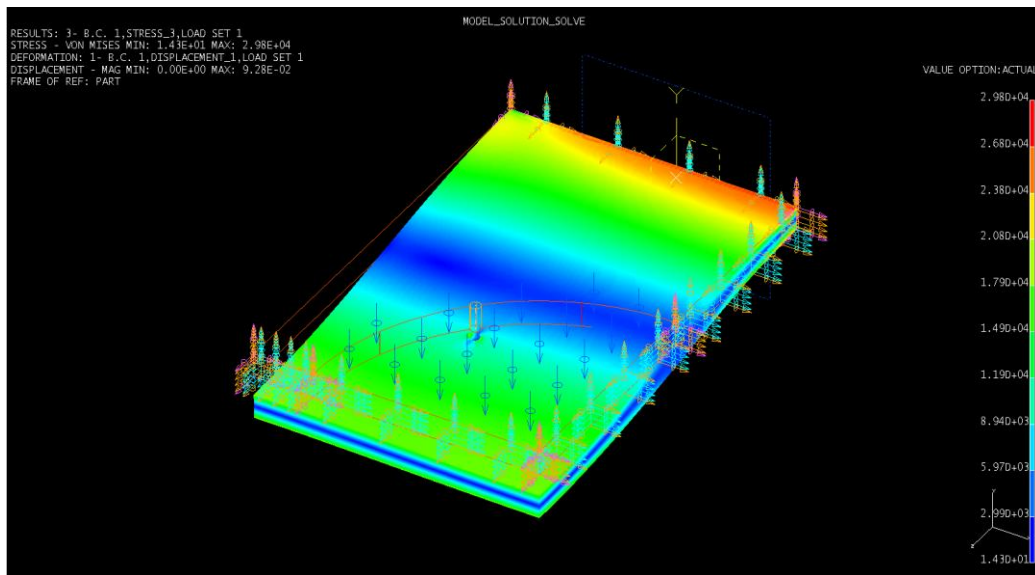
An air spring mounted to a support plate will create a pressure loading on the plate which will lead to stress and deformation in the plate. This engineering note determines the maximum stress and the deflection that will result from the air spring. The maximum pressure that will occur within the air spring is 100 psi. This pressure is exerted within a circle, centered on the plate, which has a diameter of 19". The plate was modeled using the I-DEAS modeling and finite element analysis software. A one-quarter section of the plate was modeled and constraints were added in order to simulate the symmetry of the plate. A pressure loading was placed on a quarter-circle section where the center of the plate would be. Several mesh sizes were applied to the plate until a trend developed in the resulting maximum stress and deflection.



**Figure 1: Mesh Size = 0.38, Maximum Stress = 28.7 ksi, Maximum Deflection = 0.093 in.**



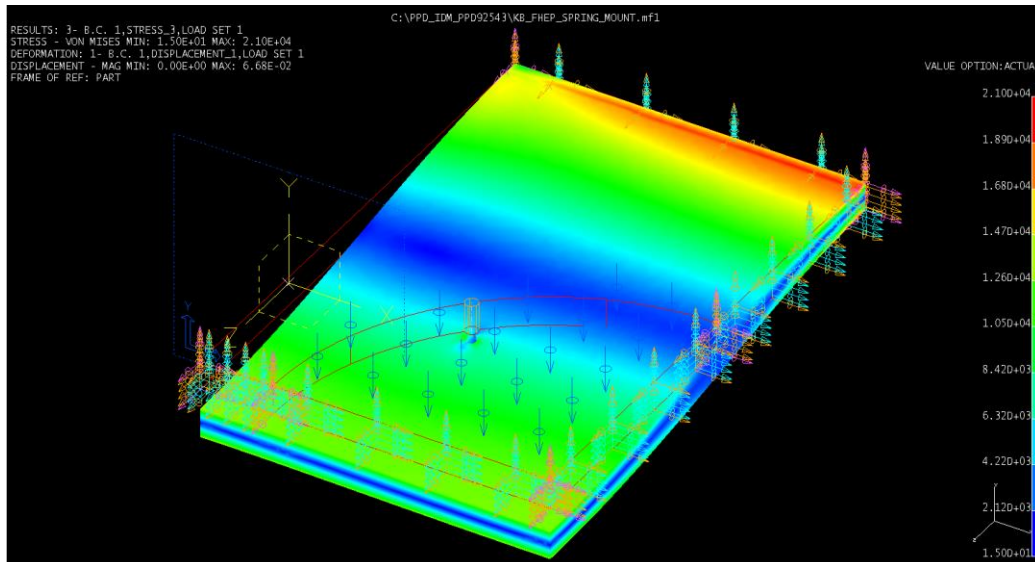
**Figure 2: Mesh Size = 0.25, Maximum Stress = 29.2 ksi, Maximum Deflection = 0.093 in.**



**Figure 3: Mesh Size = 0.19, Maximum Stress = 29.7 ksi, Maximum Deflection = 0.093 in.**

The stress in the plate is rather high, considering the yield strength of ASTM-A36 structural steel is 36 ksi (tension). With an allowable stress limit of 0.6 times the yield strength of the plate, or 21 ksi, the plate is well above the allowable value.

Next, the pressure in the air spring was lowered until the maximum stress in the plate fell below the maximum allowable limit. The pressure at which this occurred was 72 psi.

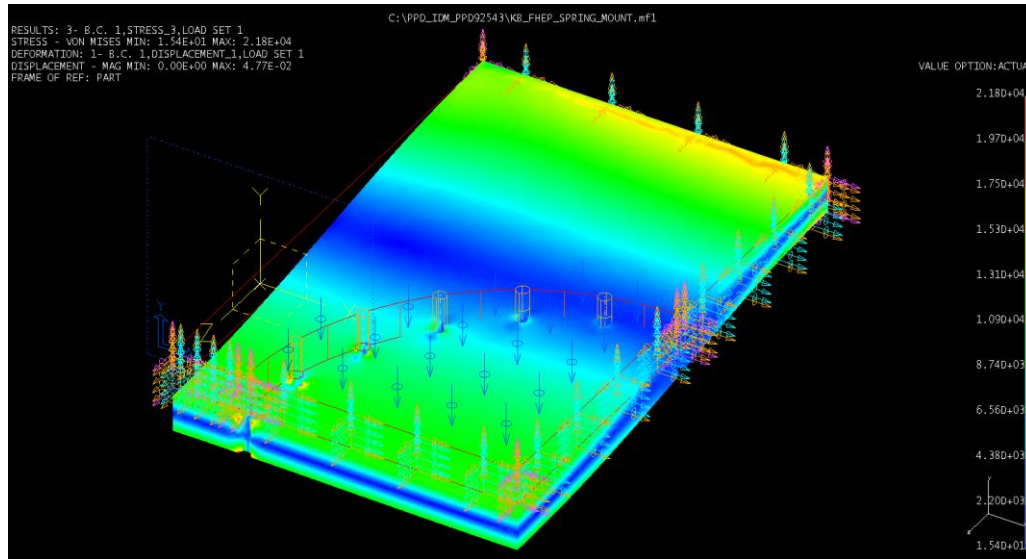


**Figure 4: Pressure = 72 psi, Maximum stress = 21.0 ksi, Maximum deflection = 0.067 in.**

## Stress-reducing Methods

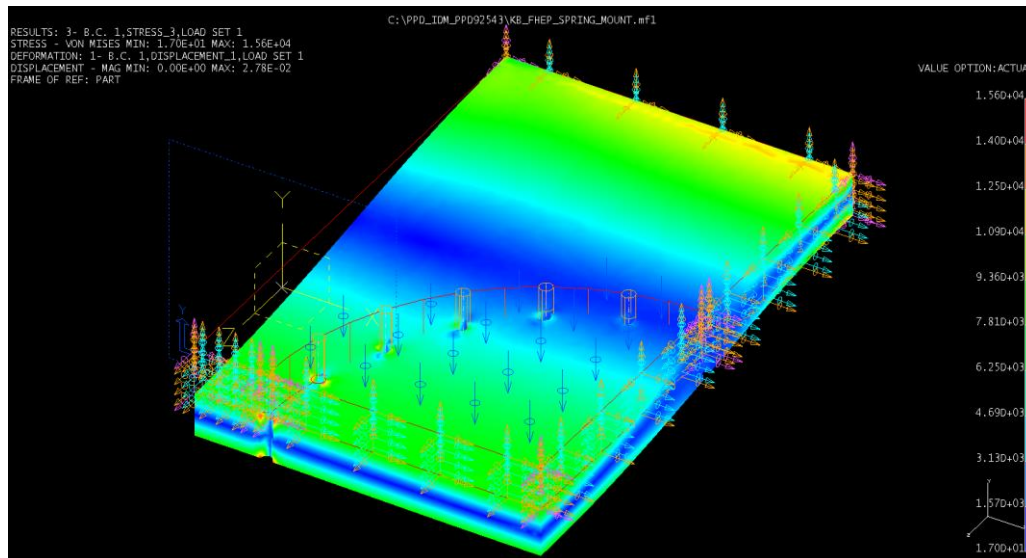
### Thicker plate

The easiest way to decrease the stresses in the plate would be to increase the plate's thickness. Simply by increasing the thickness from 1" to 1.25", the maximum stress in the plate decreased from a maximum of 29 ksi to a maximum of about 22 ksi.



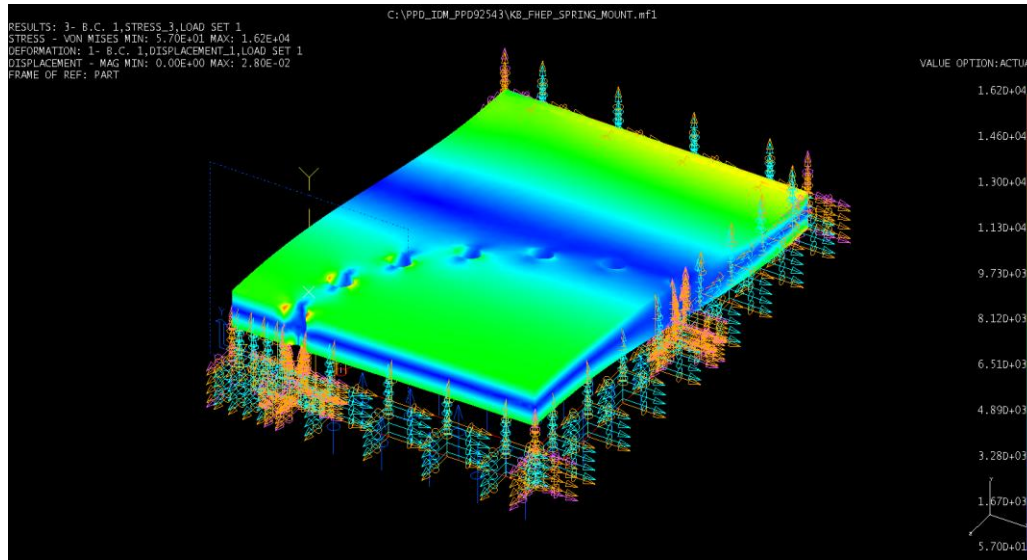
**Figure 5: Thickness = 1.25", Mesh size = 0.38, Maximum Stress = 21.7 ksi, Maximum deflection = 0.048 in.**

By further increasing the thickness to 1.5", the maximum stress is reduced to around 16 ksi.

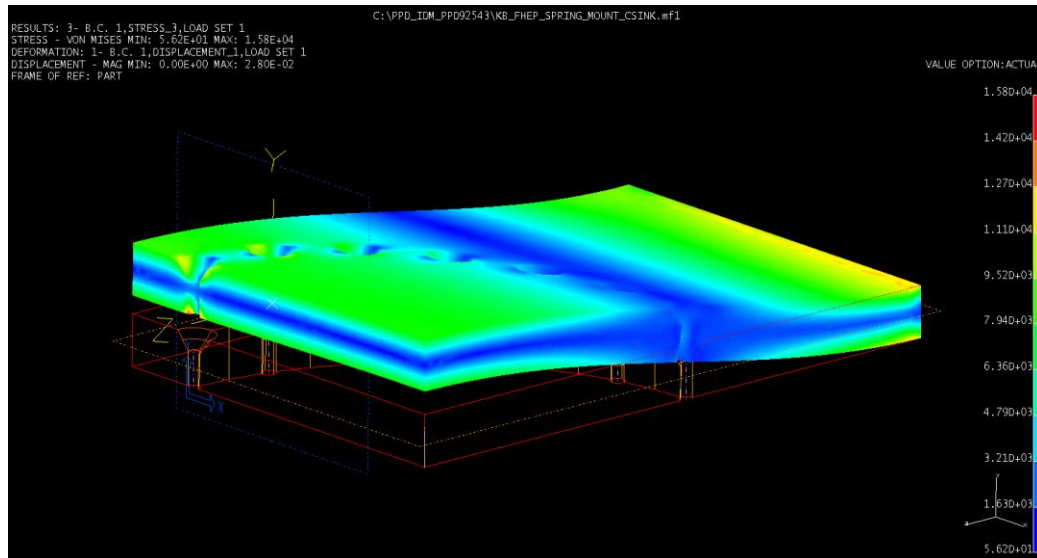


**Figure 6: Thickness = 1.5", Mesh size = 0.38, Maximum stress = 15.6 ksi, Maximum deflection = 0.028 in.**

The main issue involved in thickening the plate is that this may introduce the need to counter-bore or counter-sink the holes of the plate. The bolts of the air spring may not be long enough to fully tighten them if a thicker plate were to be used. In order to determine what effect a counter-bored or counter-sunk hole would have on the stress, the plate was modeled with these modifications and the maximum stress was determined. For a 1.5" thick plate, the maximum stress for both cases was below the maximum allowable value.



**Figure 7: 1.5" Thick plate w/ counter-bored holes, Maximum stress = 16.2 ksi, Maximum deflection = 0.028 in.**



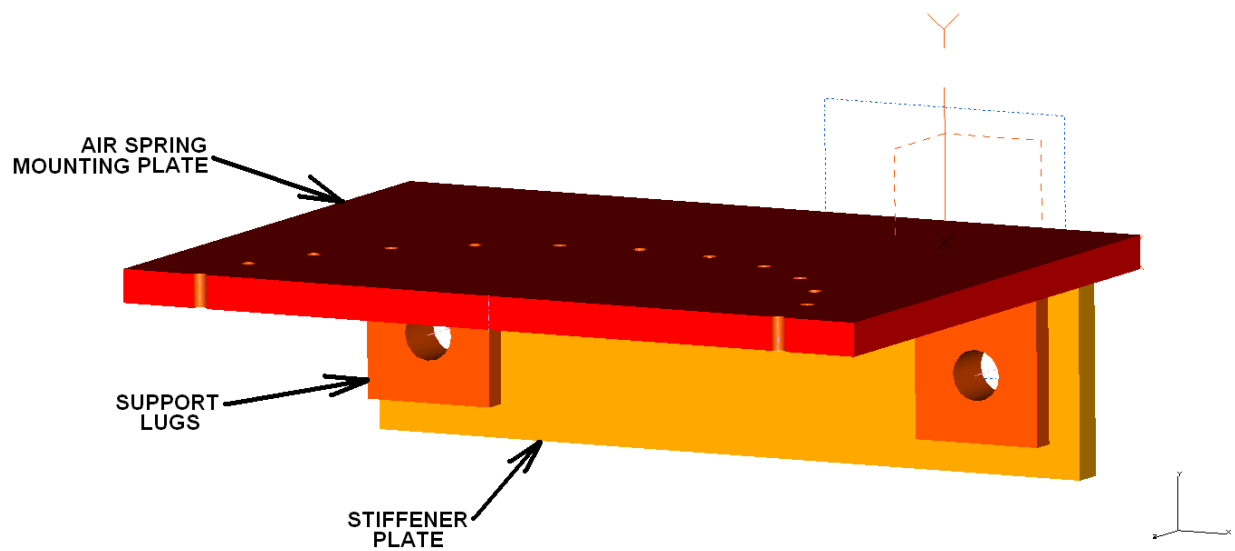
**Figure 8: 1.5" Thick plate w/ counter-sunk holes, Maximum stress = 15.8 ksi, Maximum deflection = 0.028 in.**

## Stiffeners

Another option that was analyzed was to attach a stiffener across the ends similar to what is currently in place in the CDF detector hall.



**Figure 9: Image from CDF Detector Hall**

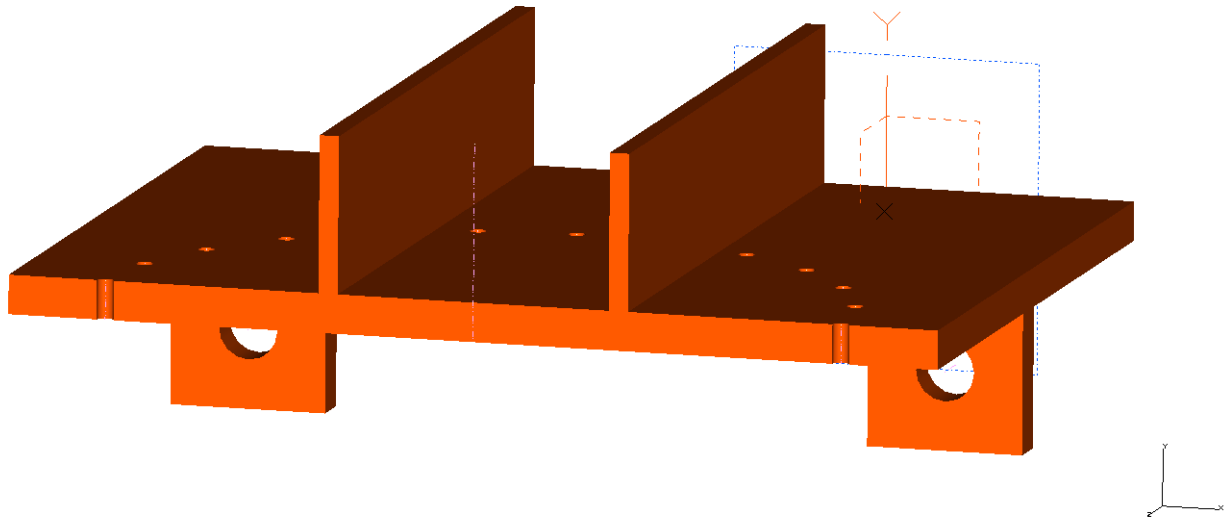


**Figure 10: I-DEAS rendering of support plate assembly**

An issue with this setup is that with the maximum pressure load, there is an increased stress at the edge of the stiffener plate. This increased stress results from a moment acting at the edge of the stiffener plate that is a result of the pressure of the air spring.



Without the stiffener plate attached to the support lugs, the maximum stress is still above the allowable limit. In order to decrease the maximum stress, two different arrangements of stiffeners were placed across the top of the plate. The first arrangement uses two stiffeners, spaced evenly across the top.



**Figure 11: Air spring mounting plate with 2 stiffeners**

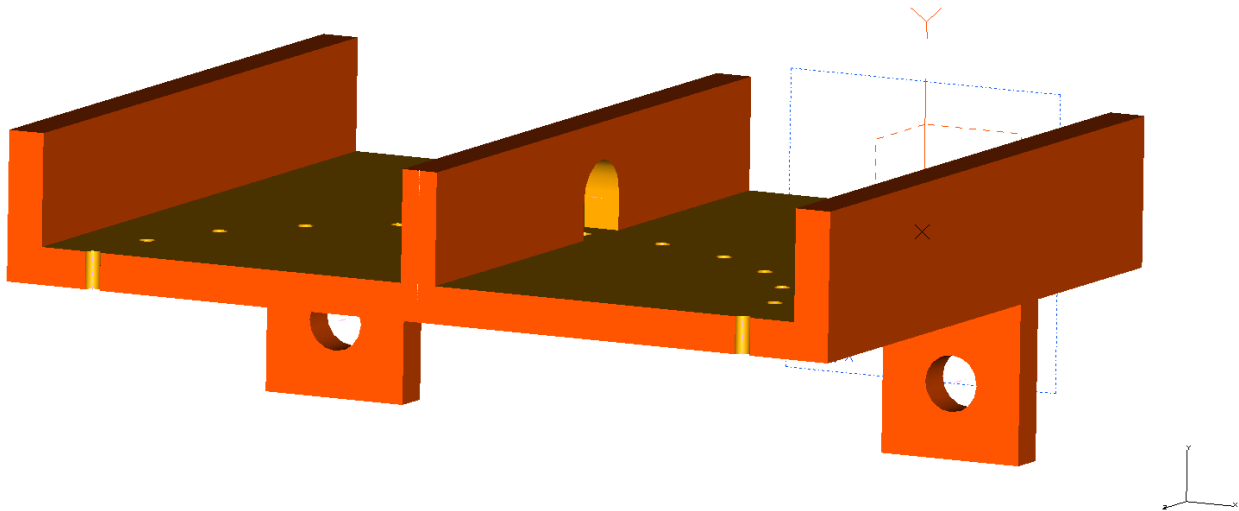
Using this setup, two different stiffener thicknesses,  $\frac{1}{2}$ " and  $\frac{3}{4}$ ", were tested. These two thicknesses were used because these values were the widest that could be used without having to cut holes in the stiffeners to allow a nut to be tightened on the bolt. The stiffener height was varied between 1" and 12". As the height of the stiffener increased, the maximum stress decreased. As can be seen in the table below, the maximum stress in the plate for both thicknesses hit a plateau right around 23 ksi. Since this is still above the maximum allowable stress, the two stiffener setup would be viable.

**Table 1: Stress values for various stiffener heights and thicknesses (2 stiffeners)**

Thickness	Height	$\sigma$
0.5	1	51.5
	2	44
	3	37.9
	4	32.7
	5	28
	6	26.2
	8	24.4
	10	23.5
	12	23.1

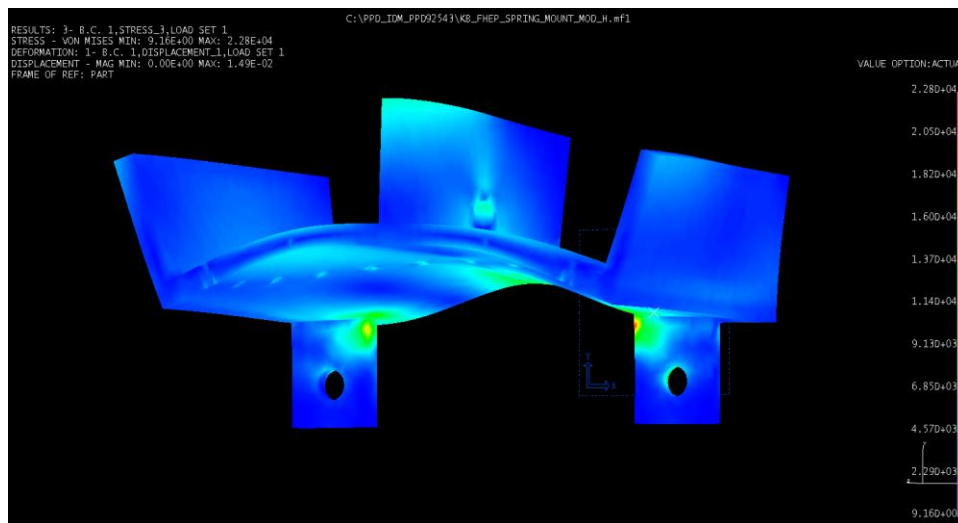
Thickness	Height	$\sigma$
0.75	1	50.2
	2	40.9
	3	33.6
	4	30.7
	5	26.7
	6	25.3
	8	25.2
	10	23.2
	12	22.7

The other arrangement of stiffeners was one on each of the edges and another running down the middle of the air spring mounting plate. In this arrangement, a hole had to be cut through the middle stiffener to allow for a nut to be tightened on the bolt.



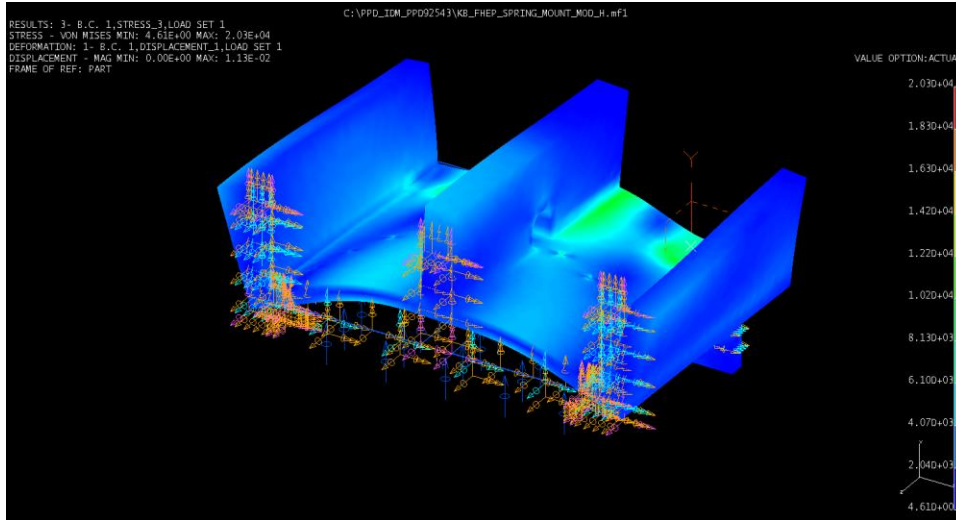
**Figure 12: Air spring mounting plate with 3 stiffeners**

For this arrangement, several different variations of thicknesses and heights for the different stiffeners were analyzed. Not surprisingly, the best results came when the thickness and height of the stiffeners were as great as possible. For example, a plate with stiffeners with a thickness of 1" each and a height of 6" had a maximum stress of about 23 ksi, while a plate that had outside stiffeners with a thickness of 1.5", a middle stiffener with a thickness of 2" and height of 6" has a maximum stress of 20.3 ksi.



**Figure 13:  $T_{OUT} = 1"$ ,  $T_{MID} = 1"$ ,  $H = 6"$ , Maximum stress = 22.8 ksi,  
Maximum deflection = 0.015 in.**





**Figure 14:  $T_{OUT} = 1.5''$ ,  $T_{MID} = 2''$ ,  $H = 6''$ , Maximum stress = 20.3 ksi,  
 Maximum deflection = 0.011 in.**

For the three stiffener arrangement, the only results that fell within the allowable range for maximum stress occurred when using thicknesses and heights that would be rather large for the plate assembly. The results can be seen in the table below.

**Table 2: Stress values for various stiffener heights and thicknesses (3 stiffeners)**

T_OUT	T_MID	H	$\sigma$
1	1	1	43.1
		2	35.1
		3	27.6
		4	24.9
		5	24.1
		6	22.8
		8	23.2
		10	22.9
		12	22.7
1	1.25	1	43.4
		2	36.7
		3	27.1
		4	26
		5	23.5
		6	22.9
		8	23.3
		10	23
		12	21.7
1	1.5	1	43.3
		2	34.8
		3	26.8
		4	24.5
		5	23.4
		6	22.7
		8	21.9
		10	21.7
		12	22.8

T_OUT	T_MID	H	$\sigma$
1.25	1	1	41.8
		2	33.5
		3	26.4
		4	23.9
		5	22.6
		6	22.1
		8	21.1
		10	20.8
		12	21.8
1.25	1.25	1	41.5
		2	33.6
		3	27.2
		4	25.1
		5	22.2
		6	21.9
		8	20.8
		10	20.5
		12	20.5
1.25	1.5	1	41.9
		2	35.3
		3	27.3
		4	23.7
		5	22.4
		6	23
		8	22.3
		10	20.6
		12	20.7

**Table 2 (continued)**

T_OUT	T_MID	H	$\sigma$
1.5	1	1	41.3
		2	32.2
		3	26.6
		4	22.9
		5	22.8
		6	22.2
		8	21.5
		10	21.2
		12	20.9
1.5	1.25	1	41.1
		2	32.2
		3	26.4
		4	22.6
		5	22.9
		6	22.2
		8	19.9
		10	21.2
		12	19.3
1.5	1.5	1	40.1
		2	31.7
		3	24.6
		4	22.4
		5	21.3
		6	20.8
		8	20
		10	19.8
		12	20.6

T_OUT	T_MID	H	$\sigma$
1.5	2	1	40.1
		2	32.9
		3	24
		4	21.9
		5	20.9
		6	20.3
		8	19.7
		10	19.1
		12	20.1
1.5	2.5	1	39
		2	30.9
		3	23.7
		4	21.7
		5	21.8
		6	20
		8	19.5
		10	20.2
		12	18.9
1.5	3	1	38.6
		2	31.1
		3	23.3
		4	21.5
		5	20.4
		6	20.9
		8	19.3
		10	18.7
		12	18.5

## **Conclusion**

The best option for reducing the stress in the plate to within the allowable range would be to increase the thickness of the plate. Even if a counter-bore or counter-sink would need to be added to the bolt holes in the plate, the maximum stress is still within the allowable range. It would probably be the easiest of the stress reduction methods to produce, and it provides the greatest decrease in stress compared to the amount of work that would have to be done.